

REMARKS

In response to the Office Action mailed December 12, 2006, Applicant respectfully requests reconsideration. Claims 1-21 were previously pending in this application. By this amendment, Applicant is canceling claims 2-5, 8, 13-15 and 18-21 without prejudice or disclaimer. Claims 1, 6, 7, 9-12, 16 and 17 have been amended. New claims 22-34 have been added. As a result, claims 1, 6, 7, 9-12, 16, 17 and 22-34 are pending for examination with claims 1 and 22 being independent.

I. Rejections Under 35 U.S.C. §102

The Office Action rejects claims 1-18 under 35 U.S.C. 102(e) as purportedly being anticipated by the paper entitled “An Image-based Technique for Low Velocity Free-surface Flows,” (Schone). While Applicant believes that the claims, as previously presented, distinguish over Schone, the claims have been amended herein to specifically point out the distinctions. In particular, the claims have been amended to clearly recite that the images are processed at multiple scales/resolutions. Schone is completely silent in this respect.

Schone discloses a technique that improves upon conventional particle image velocimetry (PIV), which is an imaging technique for measuring particle displacement by processing successive images obtained at different times, and in particular, by taking cross-correlations of regions in the successive images (see e.g., “Principles of PIV” beginning on page 11 of Schone). Schone’s technique is referred to as surface wave image velocimetry (SWIV), and discloses new methods for adding marking material to a fluid flow, a process referred to as “seeding” (see e.g., “Seeding” on page 12 of Schone). However, SWIV uses the standard cross-correlation methods of PIV. In particular, Schone discloses performing cross-correlations using a *single size for the interrogation areas*. That is, Schone determines particle displacement at a single scale.

The Office Action asserts that Figurea 4.19 and 4.20 disclose using different sizes for the interrogation areas. However, Figures 4.19 and 4.20 show two separate analyses, each performed using separate interrogation area sizes. The two analyses are entirely independent of one another. The text describing these figures makes it clear that Schone is not performing multi-scale processing on the images, but rather trying different interrogation region sizes in entirely separate experiments in an effort to identify the optimal single size interrogation area for Schone’s particular application.

Schone does not mention using different interrogation region sizes in a single processing of the images to obtain a single displacement image. That is, in Schone, one displacement image was generated using a 32 x 32 pixel interrogation area (Figure 4.19) and the other displacement image was generated using a 64 x 64 pixel interrogation area (Figure 4.20). However, only one size interrogation area was used to determine the entire respective flow map. Schone makes it clear that, once selected, the same size interrogation area is used for the entire evaluation. Two different sized interrogation areas are never disclosed as being used together in a single multi-scale processing. In particular, Schone discusses the size of the interrogation areas at two locations in the paper (i.e., page 44 and page 55), each of which are reproduced in full below. The first two paragraphs below Figure 3.17 on page 44 state:

The correlation algorithm and the Fast Fourier Transform (FFT) techniques were chosen, every picture (frame) was exposed just once. A too small interrogation area (IA) might fail to detect the actual flow correctly, while a too large IA does not improve the result considerably and takes a very long time for evaluation. *After trying several settings for the IA that were ranging from 16 x 16 pixels up to 64 x 64 pixels, finally a size of 32 x 32 pixels proved to be the best compromise.* (Emphasis).

Initially the size of the grid was set to 16 x 16 pixels or larger. This was done to save time and was sufficient to get an idea about the observed flows. Later the grid size was decreased to 10 x 10 pixels. The evaluation took considerably longer now, but yielded in much denser spatial information about the celerities of the waves around the fan.

Schone recognizes that the choice of interrogation area size effects accuracy and computation time and discloses selecting a interrogation region that is a compromise for a particular application with respect to the competing benefits and drawbacks. That is, Schone discloses identifying a single interrogation area size that best balances the trade-offs inherent between small and large area sizes. Schone does not, however, disclose using interrogation areas of different sizes in a single multi-scale computation. In the section entitled "Choice of Size of Interrogation Area" on page 55, Schone reiterates that a single empirically determined interrogation area size was used for the correlation algorithm. The above section states:

The most important setting to be done in PIV software is the choice of the size of the interrogation area (IA). For several experiments identical data material was evaluated with different software settings and the result were compared in terms of precision, reliability and efficiency.

The Figures 4.19 and 4.20 show the Tecplot output of an evaluation of 100 pictures for setting that differ only in the chosen size of the IA. A smaller IA is more sensitive to effects like local wave reflections on the flume walls because the correlation is done for a smaller area only. This can be seen in the vector field and the velocity-contour lines on the upper and lower edge of Figure 4.19. However, in terms of magnitude and direction of the vectors along the centerline both alternatives can be regarded as equal for the given conditions. Because the evaluation with a larger IA is always more time consuming – an IA of 32 x 32 takes less than half of the time than an IA of 64 x 64 – the former size, *32 x 32 pixels, was chosen for the remainder of the experiments.*

Although Schone recognizes that different interrogation sizes may generate results of different precision, reliability and efficiency, Schone nowhere discloses or suggests using different interrogation sizes in the same experiment to generate a single displacement map. That is, Schone does not disclose or suggest an algorithm wherein the scale/resolution is varied over iterations of a single processing of the pair of images depending on the results of the previous iteration. Rather, Schone discloses choosing one single interrogation size to use for the entire PIV computation. In fact, Schone specifically points out that because only one size is ultimately used in the PIV computation, it is important to select that size carefully. Applicant alone has disclosed and developed a method that obviates the need to carefully select a single interrogation region size for the displacement computation. Rather, the interrogation region size can be iteratively adjusted during the computation of a single displacement map based on the resulting correlation data.

Claim 1, as amended, recites a method of processing at least first and second images of an image flow of an object to determine a relative displacement map of elements of the image flow over a predetermined time interval, the method comprising recording a first array of pixel values associated with the first image of the image flow, recording a second array of pixel values associated with the second image of the image flow, defining a first plurality of interrogation regions on the first array of pixel values of the image flow, each of the first plurality of interrogation regions including a first number of pixels indicative of a first resolution at which to correlate the first and second images, determining a first correlation plane formed from correlations between each of the first plurality of interrogation regions and at least one associated region in the second array of pixel values, the first correlation plane including a maximum correlation value for each of the first plurality of interrogation regions indicating which of the at least one associated regions

each of the first plurality of interrogation regions are most highly correlated with, determining a direction and magnitude associated with each of the maximum correlation values which represents the relative displacement between each of the first interrogation regions and the respective most highly correlated associated region in the second array of pixels over the predetermined time interval, for each of the determined direction and magnitude that is resolved, adding the direction and magnitude to the displacement map at a location associated with the respective first interrogation region, for each of the determined direction and magnitude that is unresolved, expanding the associated first interrogation region to form a second plurality of interrogation regions, each of the second plurality of interrogation regions having a second number of pixels, greater than the first number of pixels, indicative of a second resolution at which to correlate the first and second images and determining a second correlation plane formed from correlations between each of the second plurality of interrogation regions and one or more associated regions in the second array of pixel values, the second correlation plane including a maximum correlation value for each of the second plurality of interrogation regions indicating which of the at least one associated regions each of the second plurality of interrogation regions are most highly correlated with, and for each of the determined direction and magnitude that is resolved, adding the direction and magnitude to the displacement map at a location associated with the respective second interrogation region.

Nowhere does Schone disclose or suggest correlating first and second images using a first plurality of interrogation regions “including a first number of pixels indicative of a first resolution at which to correlate the first and second images” to determine a direction and magnitude associated with each of maximum correlation values in a first correlation plane representing the relative displacement between each of the first interrogation regions and the respective most highly correlated associated region and wherein *if the direction and magnitude are resolved, adding the direction and magnitude at appropriate locations in a displacement map, and otherwise, expanding the unresolved interrogation regions to include a second number of pixels indicative of a second resolution at which to correlate the first and second images to determine direction and magnitude associated with each of maximum correlation values at the second resolution, likewise adding*

resolved directions and magnitudes to the same displacement map, as recited in claim 1. Therefore, claim 1 patentably distinguishes over Schone and is allowable condition.

Claims 6, 7, 9-12 and 16 and 17 depend from claim 1 and are allowable based at least on their dependency.

Claim 22 recites a method of processing a first image and a second image of a scene obtained at a first time and a second time, respectively, to determine relative displacement of elements in the images between the first time and the second time, the method comprising grouping pixels in the first image into a first interrogation region consisting of a first number of pixels indicative of a first desired scale, correlating the first interrogation region with a first plurality of associated regions in the second image to obtain a respective first plurality of correlation values, if a maximum correlation value of the first plurality of correlation values exceeds a threshold value, determining a displacement associated with the maximum correlation value indicative of the displacement between the first interrogation region and the associated region that resulted in the maximum correlation value, and if the maximum correlation value does not exceed the threshold value, expanding the first interrogation region to include additional pixels such that the first interrogation region consists of a second number of pixels indicative of a second desired scale, and correlating the expanded first interrogation region with a second plurality of associated regions in the second image to obtain a respective second plurality of correlation values.

Schone nowhere discloses or suggests correlating a first interrogation region in the first image consisting of a first number of pixels indicative of a first desired scale with associated regions in the second image to obtain a plurality of correlation values and to perform the following: "if a maximum correlation value of the first plurality of correlation values exceeds a threshold value, determining a displacement associated with the maximum correlation value indicative of the displacement between the first interrogation region and the associated region that resulted in the maximum correlation value, and if the maximum correlation value does not exceed the threshold value, expanding the first interrogation region to include additional pixels such that the first interrogation region consists of a second number of pixels indicative of a second desired scale, and correlating the expanded first interrogation region with a second plurality of associated regions in the second image to obtain a respective second plurality of correlation values, as recited in claim 1.

That is, Schone nowhere discloses or suggests processing the correlation values to see if they exceed a threshold and, if they don't, performing correlations with a second interrogation region formed at different scale. Therefore, claim 22 patentably distinguishes over Schone and is in allowable condition.

Claims 23-32 depend from claim 22 and are allowable based at least on their dependency.

CONCLUSION

A Notice of Allowance is respectfully requested. The Examiner is requested to call the undersigned at the telephone number listed below if this communication does not place the case in condition for allowance.

If this response is not considered timely filed and if a request for an extension of time is otherwise absent, Applicant hereby requests any necessary extension of time. If there is a fee occasioned by this response, including an extension fee, that is not covered by an enclosed check, please charge any deficiency to Deposit Account No. 23/2825.

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Respectfully submitted,

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